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PHOTOCONDUCTOR SWITCH & CIRCUIT ANALYSIS
BY: CC WU, CT CHANG

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Photoconductor Switch and Circuit Analysis

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One-hundred-picosecond optical pulses with a continuous repetition frequency, from 30 MHz to greater then 1 GHz, were generated by direct RF modulation of a self-pulsating laser diode. With a peak laser pulse power about 18 mW and negligible DC optical power, these optical pulses were used to activate a photo-conductive switch for real-time signal sampling.

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Picosecond optical pulses are commonly generated by mode locking [1,2] or gain switching [3,4] of non-self-pulsating laser diodes. The gain switching is related to laser relaxation oscillation, which is the consequence of interaction between photons (with a lifetime of 1 ps) and injected carriers (with a lifetime of 1 ns) in the active region. In this paper, we report picosecond pulse generation by gain switching associated with direct RF modulation of a self-pulsating laser under DC biasing. Characteristics of typical optical pulses are pulse width (full width at half maximum) 100 ps, repetition frequency the same as the RF modulating frequency (30 MHz to greater than 1 GHz), and 18 mW peak pulse power. For a given pulse repetition frequency (or RF modulating frequency), these short optical pulses can be generated by properly adjusting RF amplitude and DC biasing on the self-pulsating laser diode.

The self-pulsating GaAlAs laser (General Optronics) used in our experiment was gain guided with large optical cavity. Optical pulses were detected with a 10 GHz PIN diode and then displayed with a sampling oscilloscope of 14 GHz bandwidth. Figure 1 shows optical pulses with 100 ps and 1.5 ns pulse widths (FWHM) from a self-pulsating laser and a non-self-pulsating laser respectively. These two lasers were under the same driving condition: $I_b = 0.9\ I_{th}$ and $I_m = 0.2[illegible]\ I_{th}$ with I_{th}, I_b and I_m being threshold current, DC biasing current and modulating RF (100 MHz) current amplitude respectively. The generation of 100 ps optical pulses is believed to be the result of fast gain switching associated with laser self-pulsation, while 1.5 ns optical pulses from the non-self-pulsating laser is the direct result of the total current exceeding the laser threshold current with no gain switching involved.

Short optical pulses of 100 ps can also be generated from a non-self-pulsating laser by RF driving with large modulation index [3]. This is due to gain switching associated with relaxation oscillation of the non-self-pulsating laser. The repetition frequency of 100 ps optical pulses found in our experiment is in the range of 30 MHz to greater than 1 GHz for the self-pulsating laser. The corresponding frequency for the non-self-pulsating laser was reported to be from 200 MHz to greater than 1 GHz [3]. Thus, self-pulsating lasers under relative small RF direct modulation can generate optical pulses with lower repetition frequency (<200 MHz) and with negligible DC power.

The repetition frequency of 100 ps optical pulses in Fig. 1 is 100 MHz, which is the laser modulating frequency. For a constant modulating current amplitude I_m, high repetition frequency is associated with high biasing current I_b and more DC optical power. Since the generation of short optical pulses at higher repetition frequency consumes more injected carriers in the active region, this can only be accomplished by a higher DC biasing current.

The most popular method of picosecond optical pulse generation is modulating the laser diode with electrical impulses from a comb generator. However, the pulse repetition frequency is discretely limited by comb generators to 100 MHz, 250 MHz, 500 MHz and 1 GHz (HP Microwave Integrated Products catalog). The advantage of picosecond optical pulses from self-pulsating laser lies in its continuous repetition frequency in the range of 30 MHz to greater than 1 GHz.

Under DC biasing slightly above threshold, this self-pulsating laser generates noisy picosecond pulses of small amplitude (several tens of uW). The pulse repetition frequency increases from 455 MHz to 2 GHz as the DC biasing is increased from 1.05 I_{th} to 1.3 I_{th}. If an external modulating current with frequency approximately the same as the laser self-pulsating frequency is superimposed on the biasing current, enhancement of self-pulsating pulses to ~ 18 mW peak optical power as shown in Fig. 2(a) was observed due to frequency locking [5]. The repetition frequency of optical pulses was observed in Fig. 2(b) to lock at the subharmonics of the modulating RF current when the DC biasing is decreased a little from that in Fig. 2(a). Subharmonic frequency locking in Fig. 2(b) puts out optical pulses less frequently and consumes less injected carriers as that due to fundamental frequency locking in Fig. 2(a). Consequently, for a given RF amplitude, DC biasing current has to decrease to obtain subharmonic frequency locking. The frequency locking may improve the temporal stability of picosecond pulse repetition, since the repetetion frequency is jointly controlled by self-pulsating frequency of the laser and RF modulating frequency.

With the modulating frequency decreased and biasing current increased from that in Fig. 1 for the self-pulsating laser, several optical pulses were generated within one cycle of the modulating current. Figure 3 shows seven optical pulses within one period of the 30 MHz modulating frequency. Here the laser driving conditions were $I_b = 0.97\ I_{th}$ and $I_m = 0.23\ I_{th}$. These seven pulses were not evenly separated. Large pulse separations at the beginning and at the end of the optical pulse train are due to the slow supply of injected carriers from the modulating current shown as the lower trace of Fig. 3. These optical pulses with non-uniform pulse separation may also be useful for signal sampling using photoconductive switches.

Signal sampling was performed using photoconductive switches with an experimental arrangement similar to that in [6]. An interdigital InP Photoconductive switch with 4 μm gap [6] activated by the previously mentioned optical pulse was used to sample the input square wave at 10 MHz repetition frequency. Both input and sampled output are shown in Fig. 4. Based upon input voltage of 700 mV and sampled output voltage of 36 mV, the switch on-resistance is estimated to be ~ 1 kΩ. The photoconductive switch has a rise time about the same as the picosecond optical pulse (<100 ps) and a longer fall time (~1 ns), which is mainly determined by photocarrier lifetime.

In conclusion, picosecond optical pulses were generated via gain switching and frequency locking associated with a self-pulsating laser. Characteristics of typical optical pulses are 100 ps pulse width (FWHM), stable pulse repetition frequency from 30 MHz to > 1 GHz, and 18 mW peak optical pulse power with negligible DC optical power. These optical pulses were used to activate an InP photoconductive switch for real-time signal sampling.

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FIGURE CAPTIONS

Fig. 1. Optical pulses from the self-pulsating laser (top trace) and a non-self-pulsating laser (bottom trace). These two lasers are under the same driving condition: $I_b = 0.9\ I_{th}$ and $I_m = 0.23\ I_{th}$, with I_{th}, I_b and I_m being the threshold current, DC biasing current, and 100 MHz modulating current amplitude respectively.

Fig. 2. Optical pulses from the self-pulsating laser under 1 GHz modulation: (a) Fundamental repetition frequency (1GHz) locking observed with $I_b = 1.25\ I_{th}$ and $I_m = 0.08\ I_{th}$; (b) Subharmonic repetition frequency (333.3 MHz) locking obtained with $I_b = 1.06\ I_{th}$ and $I_m = 0.08\ I_{th}$.

Fig. 3. Seven optical pulses with different pulse separations from the self-pulsating laser with $I_b = 0.97\ I_{th}$, $I_m = 0.23\ I_{th}$. The repetition frequency for these seven pulses is 30 MHz, which is the RF modulating frequency.

Fig. 4. Real-time sampling of 10 MHz square wave using an interdigital InP photoconductive switch activated by 100 ps pulses at 100 MHz repetition frequency.

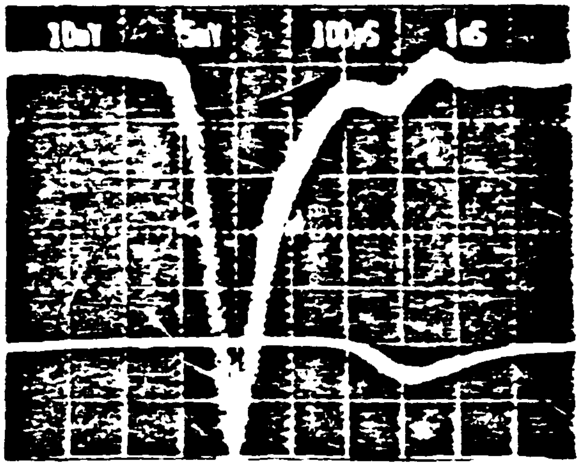

Fig 1

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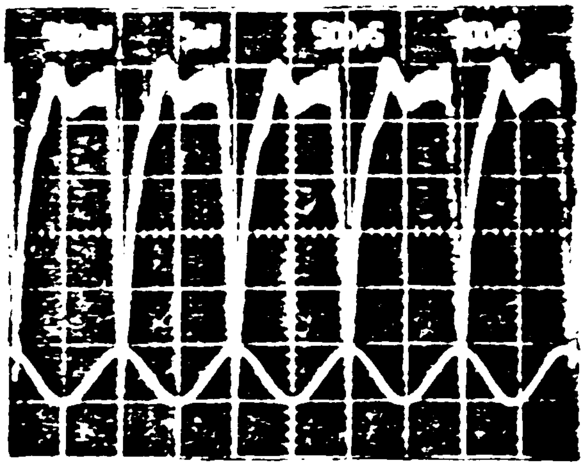

Fig 2(a)

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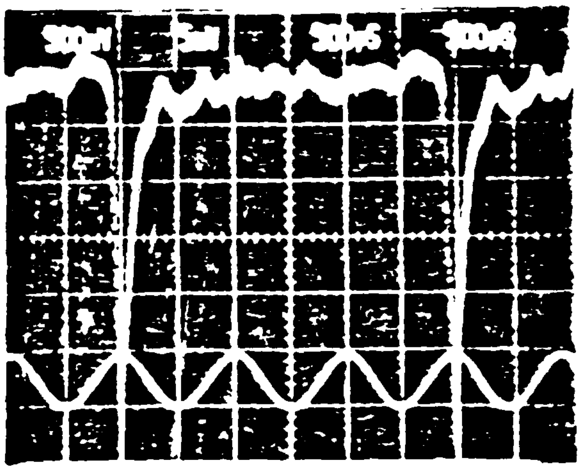

Fig 2(b)

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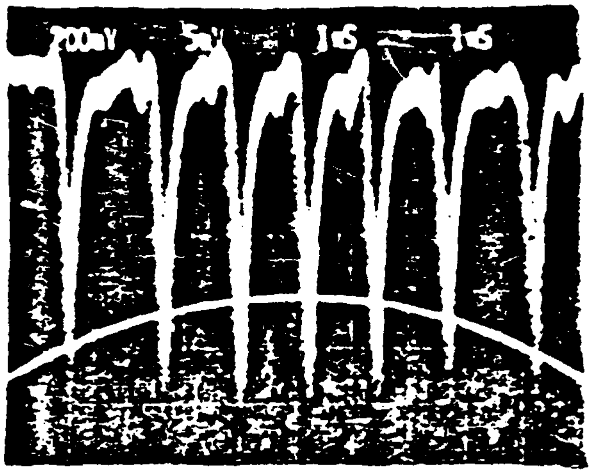

Fig 3

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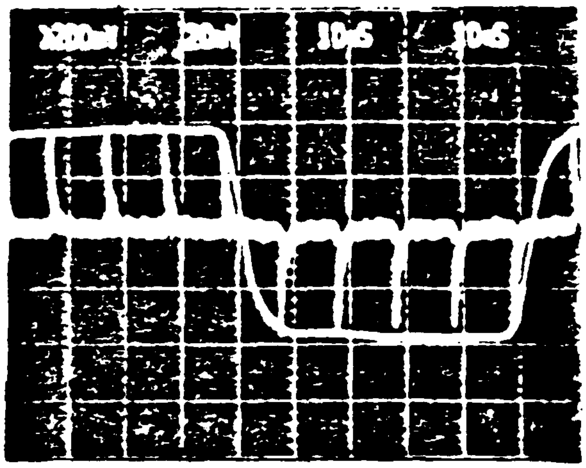

Fig 4

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